December 22, 2021

VIA ECFS

Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
45 L Street, NE
Washington, DC 20554

Re: Written Ex Parte – *AVSI Project Report 76S2-REP-04*, GN Docket No. 18-122

Dear Ms. Dortch:

On behalf of the Aerospace Vehicle Systems Institute ("AVSI") project team, AVSI is pleased to provide the attached report "Derivation of Radar Altimeter Interference Tolerance Masks. Volume II: Spurious Test Results" to support the Commission's review of the findings of the report previously filed by RTCA, "Assessment of C-Band Mobile Telecommunications Interference on Low Range Radar Altimeter Operations", which demonstrated the risk for harmful interference to radar altimeters (RAs)[1] from new 5G emissions in the 3700-3980 MHz frequency band.[2] This is the second volume of a three volume report. The first volume was filed in multiple parts on December 7 and Volume III will be released upon completion and release.[3]

This volume follows precedent and reports anonymized data using the same designations established in Volume I.

Respectfully submitted,

/s/ David Redman
Dr. David Redman – Aerospace Vehicle Systems Institute
On behalf of the AVSI AFE 76s2 project team

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1 Radar altimeters are also commonly referred to as "radio altimeters."

2 RTCA, Assessment of C-Band Mobile Telecommunications Interference on Low Range Radar Altimeter Operations, RTCA Paper No. 258-20/SC239-006 (rel. Sept. 18, 2020) ("RTCA MSG Report"), attached to Letter from Terry McVenes, RTCA, Inc., to Marlene Dortch, FCC, GN Docket No. 18-122 (filed Oct. 20, 2020).

3 *See* AVSI, *AFE 76s2 Report Derivation of Radar Altimeter Interference Tolerance Masks Volume I: Introduction, Test Procedures, and Fundamental Test Results*, attached to Letter of Dr. David Redman, AVSI, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 18-122 (filed Dec 7, 2021). Due to ECFS file size limitations, the full Volume 1 report is posted in parts. The full integrated report is available at https://avsi.aero/wp-content/uploads/2021/12/AVSI-AFE76s2-Report-ITMs-Vol-IPUBLIC.pdf.

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AFE 76s2 Report

Derivation of Radar Altimeter Interference Tolerance Masks

Volume II: Spurious Test Results

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Gary Hunter	NASA
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Table of Contents

List of Figures

List of Tables

List of Acronyms

5G	Fifth generation technology standard for broadband cellular networks
AFE	Authorization for Expenditure (for AVSI Projects)
AGL	Above Ground Level
ASRI	Aviation Spectrum Resources Inc.
AUT	Altimeter Under Test
AVSI	Aerospace Vehicle Systems Institute
AWGN	Additive White Gaussian Noise
BW	Bandwidth
CF	Center Frequency
FAA	U.S. Federal Aviation Administration
FCC	U.S. Federal Communications Commission
FMCW	Frequency Modulated Continuous Wave
IATA	International Air Transport Association
IBI	In Band Interference
ITM	Interference Tolerance Mask
ME	Mean Error
NASA	U.S. National Aeronautics and Space Administration
NCD	No Computed Data
OOBI	Out-of-Band Interference
PSD	Power Spectral Density
RA	Radar Altimeter; also commonly referred to as Radio Altimeter
RF	Radio Frequency
RTCA	RTCA, Inc. (formerly Radio Technical Commission for Aeronautics)
UC	Usage Category
UC1	Usage Category 1
UC2	Usage Category 2
UC3	Usage Category 3
VCO	Voltage-Controlled Oscillator
VSG	Vector Signal Generator
WCLS	Worst-Case Landing Scenario

Executive Summary

The Aerospace Vehicle Systems Institute (AVSI) Project AFE 76s2 – *Out-of-band Interference with Radio Altimeters* tested nine commercial radar altimeter models for their sensitivity to fundamental emissions in the 3700 – 3980 MHz band and spurious emissions in the 4200 – 4400 MHz band from new flexible use (5G) signals as proposed (and ultimately authorized) by the Federal Communications Commission (FCC) in their March 2020 Report and Order. These tests resulted in a set of interference tolerance thresholds that were provided to RTCA, Inc. for use in their Special Committee SC-239 analysis of the potential for harmful interference to radar altimeters from these new flexible use (5G) emissions. The results of the SC-239 analysis were published in a report (RTCA MSG Report) that demonstrated that there was indeed a credible risk of harmful interference to radar altimeters from new 5G emissions.

The results and implications of the RTCA MSG Report has generated considerable interest from both aviation and wireless industry stakeholders, as well as the government bodies that regulate each. This interest in the conclusions of the RTCA MSG Report has led to broad interest in reviewing the data that lead to the establishment of the interference tolerance masks that AVSI provided. This AVSI Report addresses this interest by providing both the raw data, and detailed descriptions of the derivation of these data, that establishes both the context in which the data must be interpreted and corresponding limitations on the application of these data to questions surrounding the potential for harmful interference to radar altimeters from new 5G sources. This AVSI Report also responds to some of the comments arising from public review of the RTCA MSG Report regarding test methods, selection of interference tolerance threshold criteria and other aspects of the AFE 76s2 project.

Based at Texas A&M University, AVSI is an aerospace industry research cooperative that facilitates collaborative research and technology projects for its members. This project included representatives from Airbus, Aviation Spectrum Resources Inc. (ASRI), Collins Aerospace, Embraer, Federal Aviation Administration (FAA), Garmin, Honeywell, the International Air Transport Association (IATA), Lufthansa Technik, National Aeronautics and Space Administration (NASA), Texas A&M University, Safran, and Thales. Project Participants contributed the subject matter expertise necessary to complete this project, including radar altimeter design engineers, aircraft systems integration experts, and aviation spectrum regulators.

This report is structured in three volumes:

- Volume I contains the introduction, test procedures, and test results from OOBI representative of 5G fundamental signals.
- Volume II (this document) contains the test results from in-band interference representative of 5G spurious signals. Also identifies changes to the test conditions and analysis for spurious tests.
- Volume III contains additional manufacturer-provided test results.

These are being released sequentially in separate volumes as each dataset is approved to expedite the delivery of the information to interested parties. Paragraph numbering is continuous through all volumes.

4 Spurious Test Results

4.1 Introduction to Volume II – Spurious Test Results

This report publicly documents the procedures and results of Aerospace Vehicle Systems Institute (AVSI) radar altimeter[1] (RA) interference testing performed under AVSI Project AFE 76s2 – *Out-of-band Interference with Radio Altimeters* (AFE 76s2) aimed at determining the sensitivity of existing commercial radar altimeters to new 5G signals intended to operate in the 3700 – 3980 MHz frequency band.

An introduction to the AFE 76s2 project, and details of the test procedures and test results from out-of-band interference (OOBI) representative of 5G fundamental signals are provided in *AFE 76s2 Report Derivation of Radar Altimeter Interference Tolerance Masks Volume I: Introduction, Test Procedures, and Fundamental Test Results*.[2]

This Volume II contains the test results from in-band interference (IBI) representative of 5G spurious signals. The volume also identifies changes to the OOBI test conditions and analysis necessary for in-band spurious emissions testing and analysis.

4.2 Procedure for In-Band Interference Testing

4.2.1 Test Setup

The test setup for OOBI testing presented in Figure 2-1 was largely unchanged, the primary exception being the removal of the band-stop filter from the output of the vector signal generator (VSG), as indicated in Figure 4-1.

4.2.1.1 Altimeters Under Test

The same altimeters used in the OOBI testing described in Volume I were subject to the in-band interference testing described herein using identical configurations of the system select settings and loop loss for each altitude tested. Table 2-1 lists characteristics of each altimeter tested. Altimeters were grouped by Usage Category, as described in Table 2-2. Altimeters included models that use both frequency modulated continuous wave (FMCW) transmitted waveforms and pulsed transmitted waveforms.

FMCW-based altimeters transmit narrow bandwidth continuous-wave radio frequency (RF) energy with a center frequency that is swept over a given sweep bandwidth at a given rate with either a triangular or sawtooth frequency modulation. The transmitted signal propagates to the ground, scatters off the terrain, and returns to the receive antenna of the RA. The round-trip signal delay produces a frequency offset that is detected using a homodyne detection. Pulsed altimeters detect the round trip transit time and compute the height above ground using the time separation of the transmitted and received pulses.

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[1] Radar altimeters are also commonly referred to as "radio altimeters."

[2] *See* AVSI, *AFE 76s2 Report Derivation of Radar Altimeter Interference Tolerance Masks Volume I: Introduction, Test Procedures, and Fundamental Test Results*, Doc ID 76s2-REP-03, Dec 2021. Available at https://avsi.aero/wp-content/uploads/2021/12/AVSI-AFE76s2-Report-ITMs-Vol-IPUBLIC.pdf (Volume I).

The altitude simulator shown in Figure 4-1 simulates the round trip delay and propagation losses for both FMCW and pulsed RAs. Additional details on the design and operation of RAs are available in an overview presentation available from AVSI.[3]

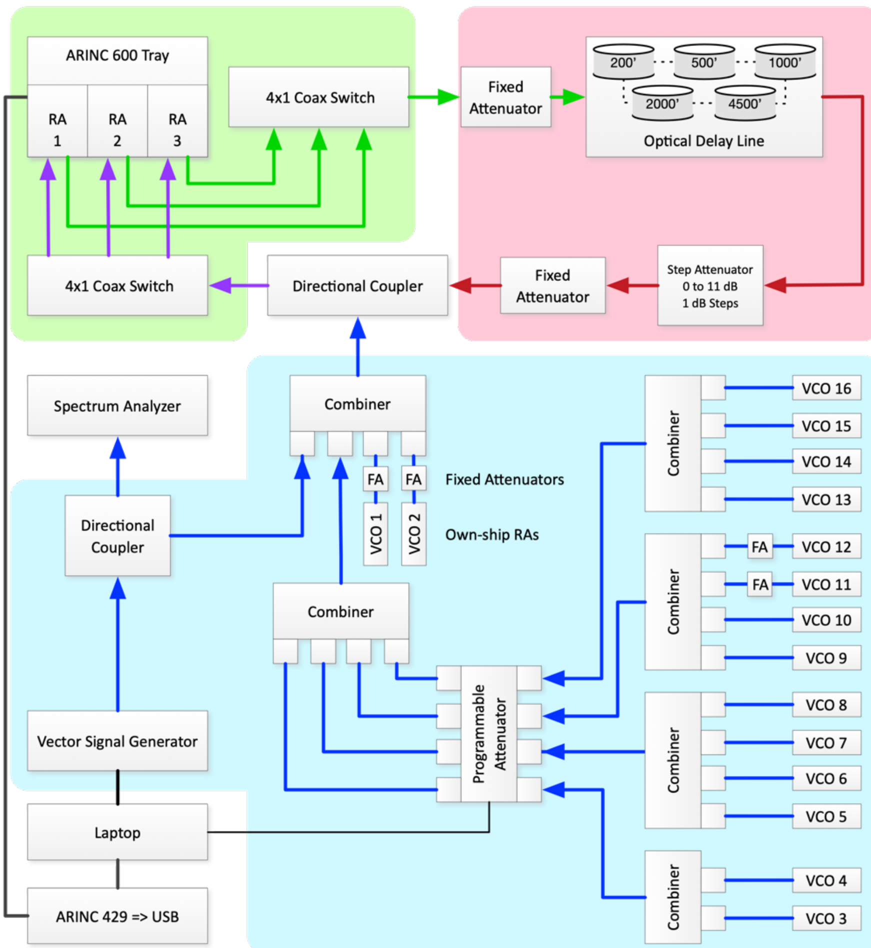

Figure 4-1: Experimental Setup for In-Band Interference Measurements

4.2.1.2 Loop Loss Settings

As described in Section 2.1.2, the total loop loss values for both the OOBI and IBI testing were derived from RTCA DO-155[4] and are provided in Table 4-1. The nominal values for external loop loss determined by the methodology described in RTCA DO-155 were adjusted to incorporate cables losses and an assumed terrain backscatter coefficient of 0.01 instead of 0.006 to meet the certification requirement for radar altimeters specified in EUROCAE ED-30.[5] Additionally, Altimeter T, operating at

[3] *See* AVSI, *Radar Altimeters: Overview Of Operation, Design, And Performance*, Seth Frick, Honeywell, Nov. 2021. Available at https://avsi.aero/wp-content/uploads/2021/12/Radar-Altimeter-Overview-of-Design-and-Performance.pdf.

[4] *See* RTCA, Inc., DO-155, *Minimum Performance Standards Airborne Low-Range Radar Altimeters* (Nov. 1, 1974) (DO-155).

[5] *See* EUROCAE, ED-30, *Minimum Performance Specification for Airborne Low Range Radio (Radar) Altimeter Equipment* (March 1980) (ED-30).

7000’ AGL, and Altimeter V at all tested heights used values 1-2 dB less than the nominal in order to ensure robust behavior of the altimeters in the absence of 5G fundamental and spurious interference signals.

There has been a persistent misunderstanding of the loop loss values used in AVSI testing, which warrants additional discussion here. In many cases, incorrect assumptions have been made concerning the choice of backscattering coefficient, assuming it corresponds to some specific choice of terrain under the approach path of an aircraft landing at an airport. In general, the radar signal transmitted from the aircraft propagates to the ground and then scatters off the ground, with a portion of the scattered energy propagating back to the altimeter receive antenna. The amount of energy scattered back to the aircraft is highly dependent on the type of terrain and the features illuminated by the transmitted radar signal.

Table 4-1: Total Experimental Loop Loss Settings

Height (ft AGL)	External Loop Loss (actual/nominal)	
	FMCW (dB)	Pulsed (dB)
200	96 / 96	96 / 97
1000	110 / 110	115 / 117
2000	116 / 116	124 / 126
5000	124 / 124	
7000	126 / 127	

Terrain scattering coefficient data is available in the literature for a wide variation of terrain types (water, farmland, grasses, urban areas, residential areas, wooded areas, desert, rocks, etc.) that can be encountered at different airport locations.[6] A dry sandy approach in the Midwest is a very different environment compared to wet asphalt in the Northwest, and RAs must operate through all these scenarios while meeting all performance requirements. The methodology provided in RTCA DO-155 and EUROCAE ED-30 attempts to incorporate these considerations, along with operational considerations such as pitch and roll of the aircraft, in backscatter coefficient values that ensure reliable operation in all conditions. However, the treatment in these standards does not allow simple comparison of the backscatter coefficient values to published terrain scattering coefficient data.

Given the assumptions incorporated in the RTCA DO-155 loop loss model, it is not appropriate to take other scattering coefficient values from the literature and simply plug them into the model directly. Likewise, it is not reasonable to try to compare the DO-155 loop loss value to other loop loss values from the literature corresponding to specific terrain types. Calculating loop losses more accurately requires substantial knowledge not only of the terrain scattering characteristics, but also of the altimeter antenna patterns and the transmission characteristics of the specific altimeter model (in the simplest case the pulse width for an unmodulated pulsed radar, or the bandwidth for a pulse compression or modulated CW radar, although more precisely for models of these latter types the radar point spread function is needed, which depends on the autocorrelation function of the transmitted waveform). Accurate loop loss calculations are also a more involved process, requiring numerical solution of what can be a fairly complex double integral.

[6] *See, e.g.*, “Handbook of Radar Scattering Statistics for Terrain,” Ulaby, F.T., Dobson, M.C. and Álvarez-Pérez, J.L., ISBN 9781630817015, Artech House (2019).

For these reasons, AVSI testing used representative cables loss values of 6 dB (representing 3 dB loss from the RA to the transmit antenna and 3 dB from the receive antenna to the RA) and DO-155 methodology for calculating external loop loss with the ED-30-specified terrain backscatter coefficient of 0.01 for setting the total loop loss values shown in Table 4-1. This reflects the requirements that all RAs approved under FAA Technical Standard Orders (TSOs) must meet in all operating conditions.

4.2.1.3 Interference Sources

Spurious interference testing consisted of operating the altimeter under test (AUT) at the nominal test altitude while subject to the in-band interference sources shown in Figure 2-3. In this case, on-board and off-board sources of frequency modulated continuous wave (FMCW) interference were simulated as described in Section 2.1.3.1.

Spurious emissions in the 4200 – 4400 MHz band (RA Band) from 5G signals operating in the 3700 – 3980 MHz band were simulated using an additive white Gaussian noise (AWGN) signal centered in the RA band at 4300 MHz with sufficient bandwidth to cover the full receive bandwidth of the AUT (or intermediate frequency bandwidth in the case of pulsed altimeters). The maximum bandwidth of the SMW200A VSG configured with the SMW-K62 software option was limited to 160 MHz, which was sufficient to cover the maximum receive bandwidth of all RAs tested. Since the subject interference signals fell within the RA band, the band-stop filter was removed and the VSG was configured to produce a 160 MHz AWGN signal centered at 4300 MHz.

4.2.2 Test Procedure

The test procedure for IBI testing was the same as that used for OOBI testing (see Section 2.2) with the exception that a single experiment was limited to a single center frequency, i.e., only one power sweep per experiment. Again, the laptop control computer recorded all measured height readings reported on the standard output as the AWGN signal power was stepped in 1 dBm power steps. Prior to running the power sweep, the AUT was turned on for a sufficient time to allow it to stabilize and experimental parameters (altimeter model, nominal height, modulation type, etc.) were recorded. Each power sweep included a baseline period with the RF power turned off as was the case for each frequency sweep in the OOBI testing.

4.3 Test Results Summary

Data collected for each RA tested are summarized in Table 4-2 for each test condition, grouped by usage category (UC). Numbers in the table are the break points in dBm and "NB" indicates that there was no break point observed. Each cell represents a single power sweep. The last two rows give the derived interference tolerance values in dBm and dBm/MHz, as described in Volume I Section 2.3.4.6, and correspond to the values provided in the interference tolerance mask (ITM) curves in the RTCA MSG Report.[7]

The following sections provide time history and statistical plots for all entries in Table 4-2 along with a description of how the threshold value was determined in each case.

Two tables are presented for each UC/height test case. The first provides a summary of the in-band FMCW interference test conditions used for the test case. The IBI representative of the worst-case landing scenario (WCLS) is only present for Usage Category 1 (UC1) and Usage Category 2 (UC2) at altitudes of 200 feet above ground level (AGL). In other cases, the presence of in-band FMCW RF

[7] *See* RTCA, Inc., *Assessment of C-Band Mobile Telecommunications Interference Impact on Low Range Radar Altimeter Operations*, RTCA Paper No. 274-20/PMC-2073 (rel. Oct. 7, 2020), *attached to* Letter of Terry McVenes, President & CEO, RTCA, Inc., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 18- 122 (filed Oct. 8, 2020) (RTCA MSG Report).

radiation from own-ship altimeters was adjusted to match the specific AUT's support of single, dual, or triplex installation. The FMCW signal type is either triangle or sawtooth, depending on the AUT, or a mixed case of both for the WCLS.

The second table provides a summary of all threshold criteria for each UC/height test case. The criterion with the lowest power that establishes the break point shown in Table 4-2 is highlighted in pink shading. In cases where more than one criterion is exceeded at the same power level, the first threshold criterion that is applied is no computed data (NCD), then mean error (ME), then 1st percentile, then 99th percentile. Thresholds that were determined by the engineering judgement of the subject matter experts are indicated with an asterisk.

Table 4-2: Measured Thresholds in dBm – In-Band Spurious Emissions
(See Vol. I § 2.3.4.6 for Derivation of ITM values)

Usage Category 1				
Altimeter	200 ft, VCOs On (WCLS) 4300 MHz AWGN	1000 ft, Own-Ship VCOs 4300 MHz AWGN	5000 ft, Own-Ship VCOs 4300 MHz AWGN	7000 ft, Own-Ship VCOs 4300 MHz AWGN
F	-45	-57	-79	
L	-52	-51	-66	
T	-40	-47		-69
X	-36	-57	-76	
Y	-42	-56	-79	
Derived ITM (dBm)	**-58**	**-63**	**-85**	**-75**
dBm/MHz	**-80**	**-85**	**-107**	**-97**

Usage Category 2			
Altimeter	200 ft, VCOs On (WCLS) 4300 MHz AWGN	1000 ft, Own-Ship VCOs 4300 MHz AWGN	2000 ft, Own-Ship VCOs 4300 MHz AWGN
A	-43	-48	-61
I	-84	-73	-69
S	-42	-52	-64
V	-64	-75	-91
Derived ITM (dBm)	**-90**	**-81**	**-97**
dBm/MHz	**-112**	**-103**	**-119**

Usage Category 3	
Altimeter	200 ft, Own-Ship VCOs 4300 MHz AWGN
A	-43
I	-68
S	-43
V	-62
Derived ITM (dBm)	**-74**
dBm/MHz	**-96**

4.4 Usage Category 1

4.4.1 200 Feet AGL

4.4.1.1 Summary

Table 4-3: UC1 200' AGL Test Conditions

Source	Rationale	Signal Type	Characteristics	Setting
VSG	5G Spurious IBI	AWGN	160 MHz centered at 4300 MHz	Power Sweep
VCOs 1-2	Own-ship multiplex installation	FMCW	CF: 4300 MHz BW/Sweep Rate per AUT	ON
VCOs 3-16	WCLS – other aircraft	FMCW	CF: 4300 MHz BW/Sweep Rate per Table 2-4	ON

Table 4-4: UC1 200' AGL In-Band Spurious Emissions Break Points

Altimeter	200 ft, VCOs On (WCLS)			
	4300 MHz			
	ME	**1%**	**99%**	**NCD**
F	-44 dBm	-45 dBm	NB	NB
L	-52 dBm	NB	NB	-52 dBm
T	-40 dBm*	NB	-41 dBm	-39 dBm
X	-36 dBm	NB	-36 dBm	NB
Y	-42 dBm	-42 dBm	NB	NB
ITM	-58 dBm			
PSD	-80 dBm/MHz			

4.4.1.2 Altimeter F

Table 4-5: UC1 RA-F 200’ AGL In-Band Spurious Emissions Break Point Summary

Center Frequency	Plot	Comments
4300 MHz	Time History Figure 4-2	Shows magnitude of change in measured height over time for increasing interference power levels.
	Statistics Figure 4-3 Figure 4-4	1st percentile measured height is less than the -2% criterion threshold at -45 dBm. Mean error exceeds the ±0.5% criterion threshold at -44 dBm.

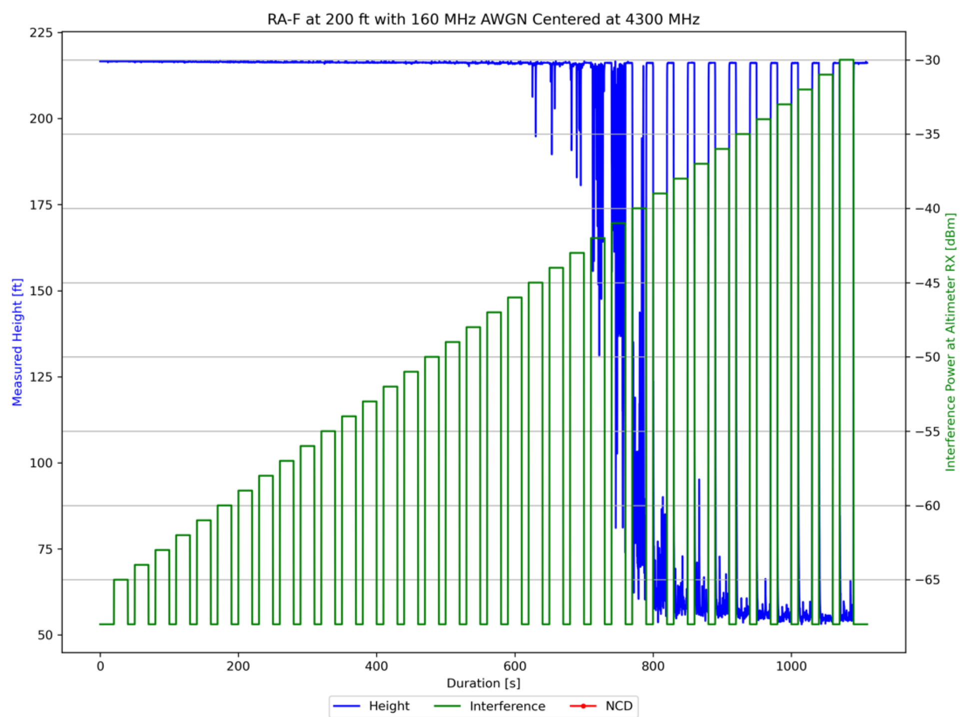

Figure 4-2: UC1 RA-F 200’ AGL Time History with AWGN at 4300 MHz

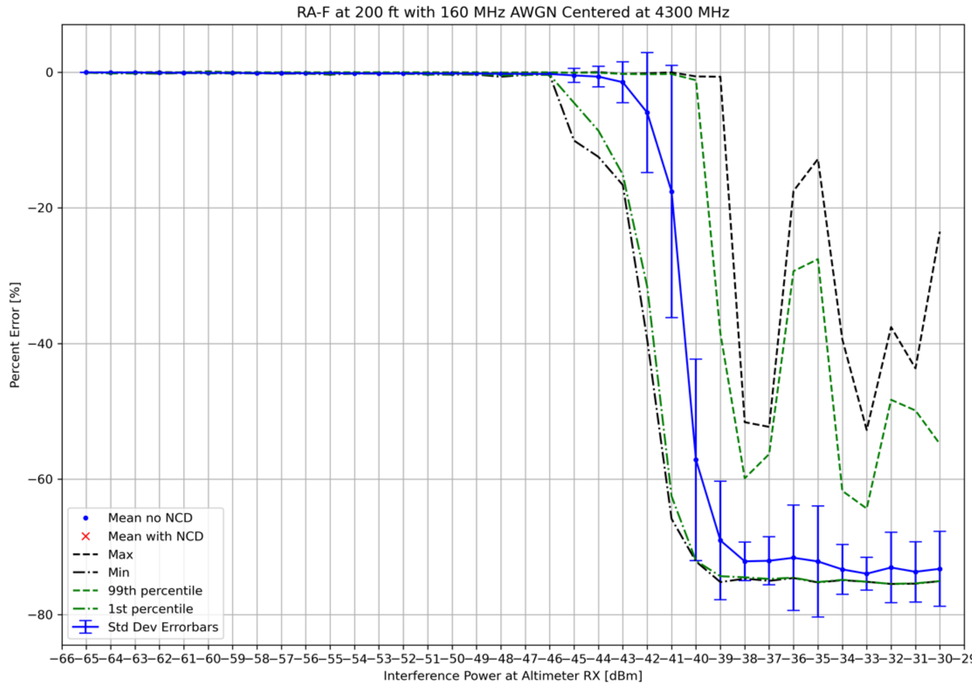

Figure 4-3: UC1 RA-F 200' AGL Statistics with AWGN at 4300 MHz – Zoomed Out

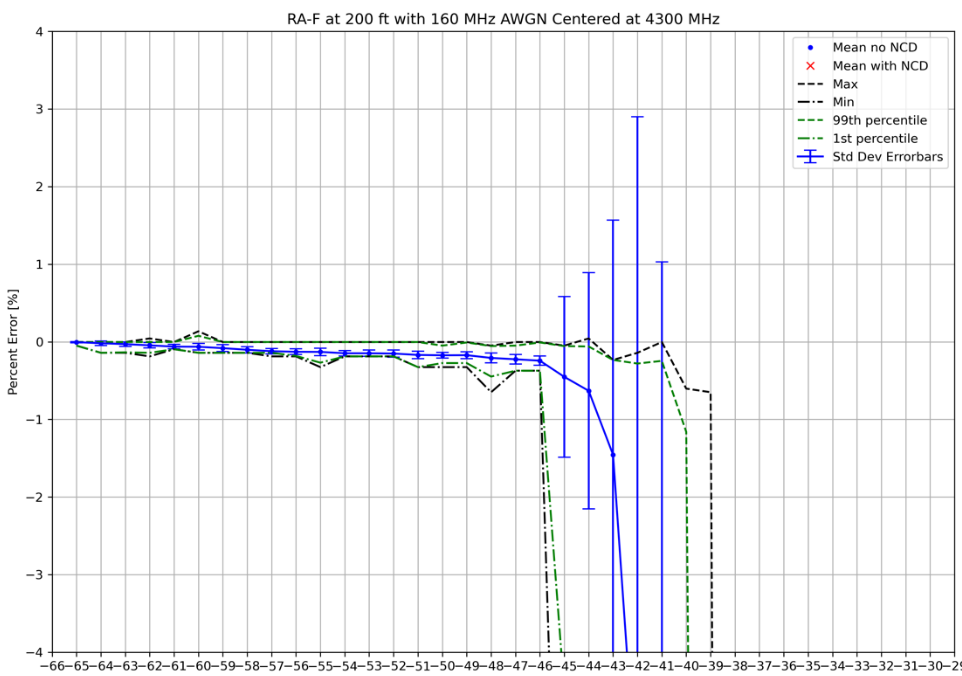

Figure 4-4: UC1 RA-F 200' AGL Statistics with AWGN at 4300 MHz – Zoomed In

4.4.1.3 Altimeter L

Table 4-6: UC1 RA-L 200' AGL In-Band Spurious Emissions Break Point Summary

Center Frequency	Plot	Comments
4300 MHz	Time History Figure 4-5	Shows magnitude of change in measured height over time for increasing interference power levels.
	Statistics Figure 4-6	An NCD occurs at -52 dBm. Mean error exceeds the ±0.5% criterion threshold at -52 dBm.

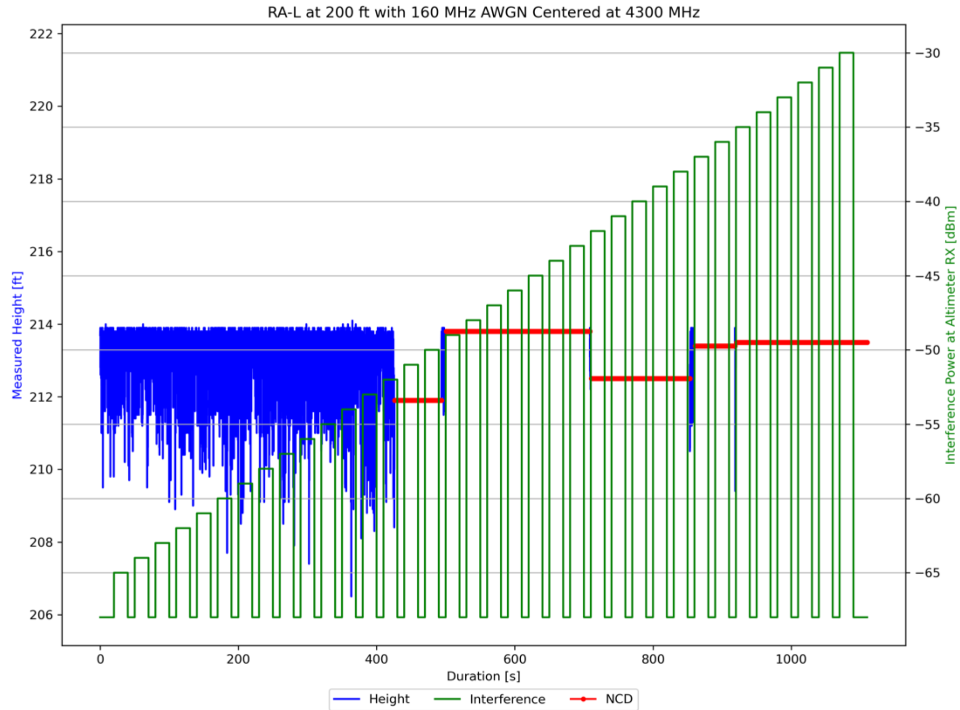

Figure 4-5: UC1 RA-L 200' AGL Time History with AWGN at 4300 MHz

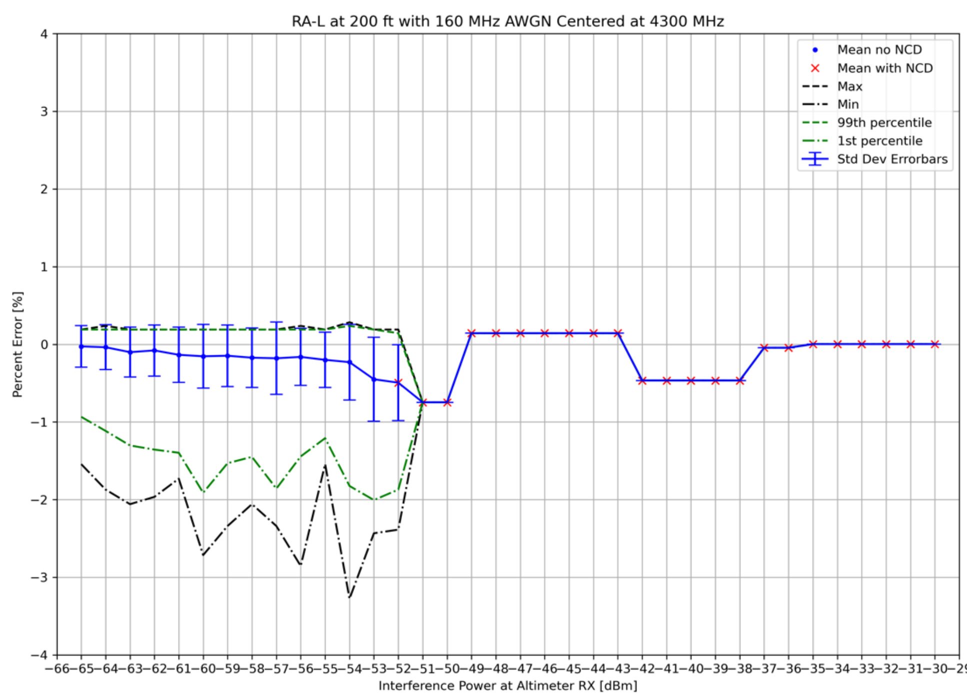

Figure 4-6: UC1 RA-L 200' AGL Statistics with AWGN at 4300 MHz

4.4.1.4 Altimeter T

Table 4-7: UC1 RA-T 200' AGL In-Band Spurious Emissions Break Point Summary

Center Frequency	Plot	Comments
4300 MHz	Time History Figure 4-7	Shows magnitude of change in measured height over time for increasing interference power levels.
	Statistics Figure 4-8 Figure 4-9	99th percentile measured height is greater than the +2% criterion threshold at -41 dBm. Mean error exceeds the ±0.5% criterion threshold at -40 dBm. An NCD occurs at -39 dBm. However, the mean error is well within the ±0.5% error threshold at -41 dBm. Subject matter experts agreed that in this case engineering judgement should be applied to set the break point at -40 dBm where the mean error exceeds the ±0.5% error threshold.

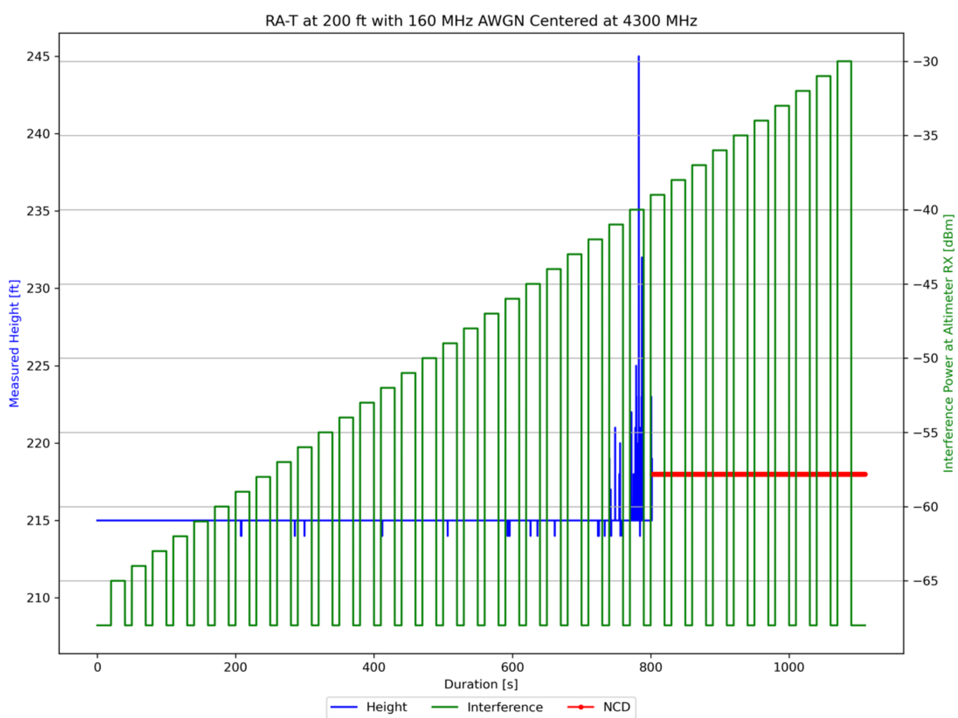

Figure 4-7: UC1 RA-T 200' AGL Time History with AWGN at 4300 MHz

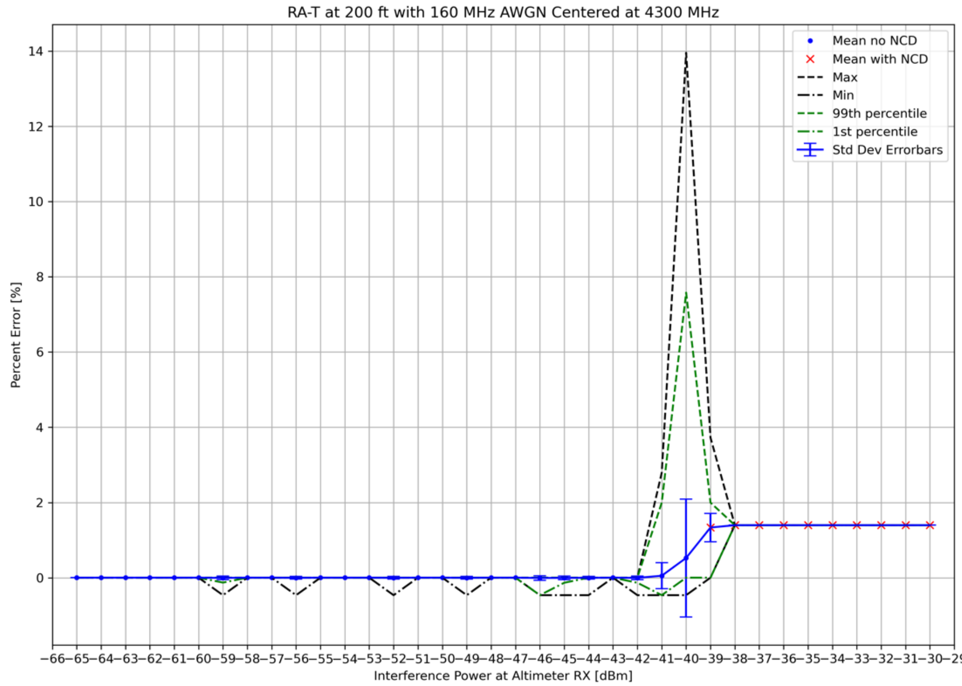

Figure 4-8: UC1 RA-T 200' AGL Statistics with AWGN at 4300 MHz – Zoomed Out

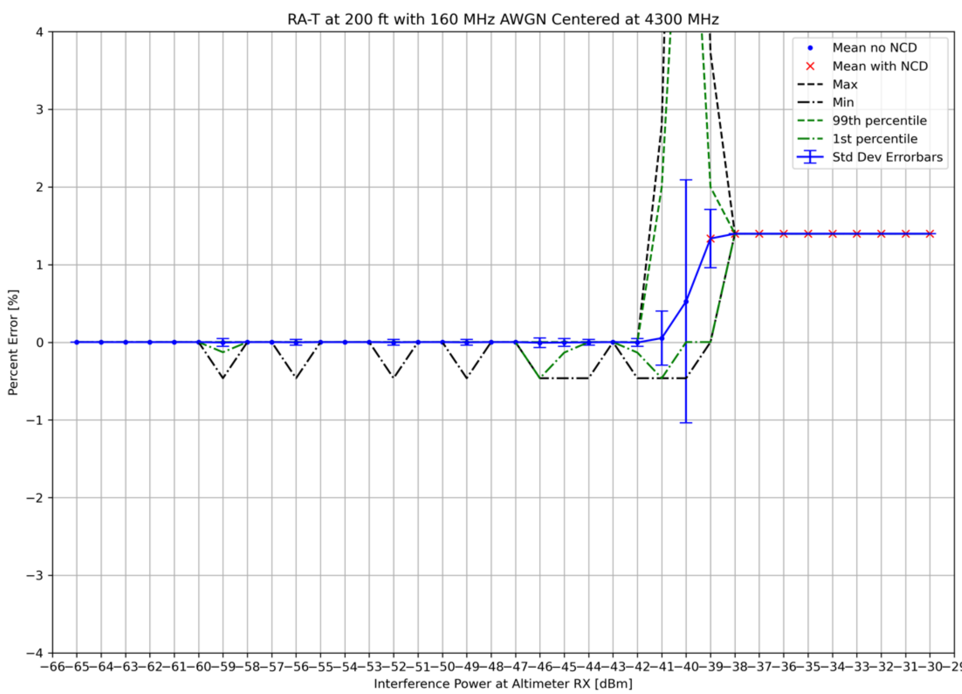

Figure 4-9: UC1 RA-T 200' AGL Statistics with AWGN at 4300 MHz – Zoomed In

4.4.1.5 Altimeter X

Table 4-8: UC1 RA-X 200' AGL In-Band Spurious Emissions Break Point Summary

Center Frequency	Plot	Comments
4300 MHz	Time History Figure 4-10	Shows magnitude of change in measured height over time for increasing interference power levels.
	Statistics Figure 4-11 Figure 4-12	Mean error exceeds the ±0.5% criterion threshold at -36 dBm. 99th percentile measured height is greater than the +2% criterion threshold at -36 dBm.

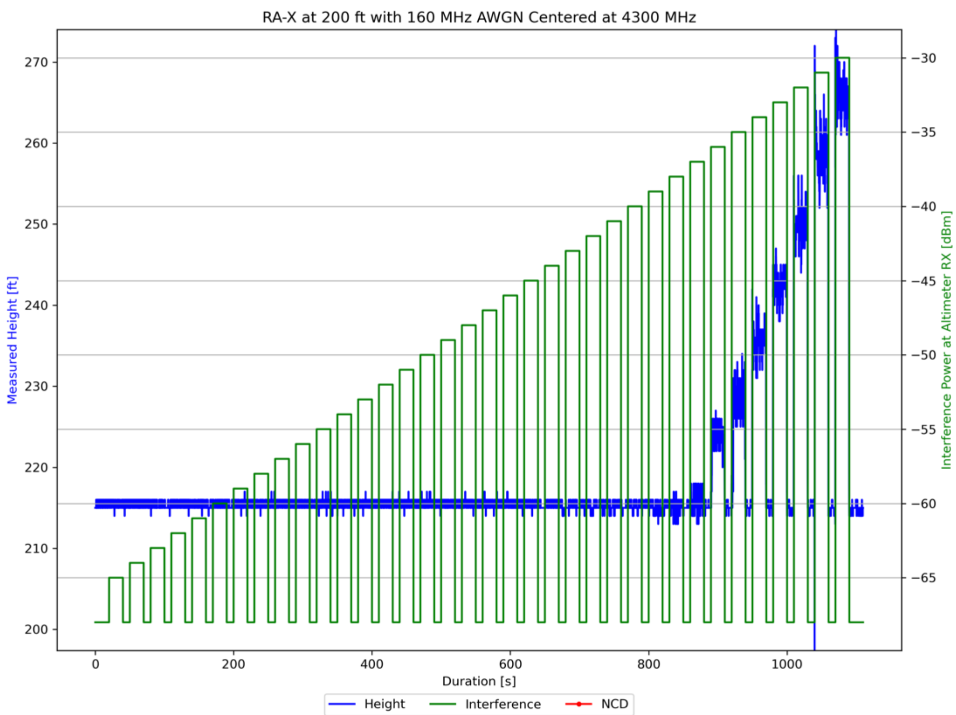

Figure 4-10: UC1 RA-X 200' AGL Time History with AWGN at 4300 MHz

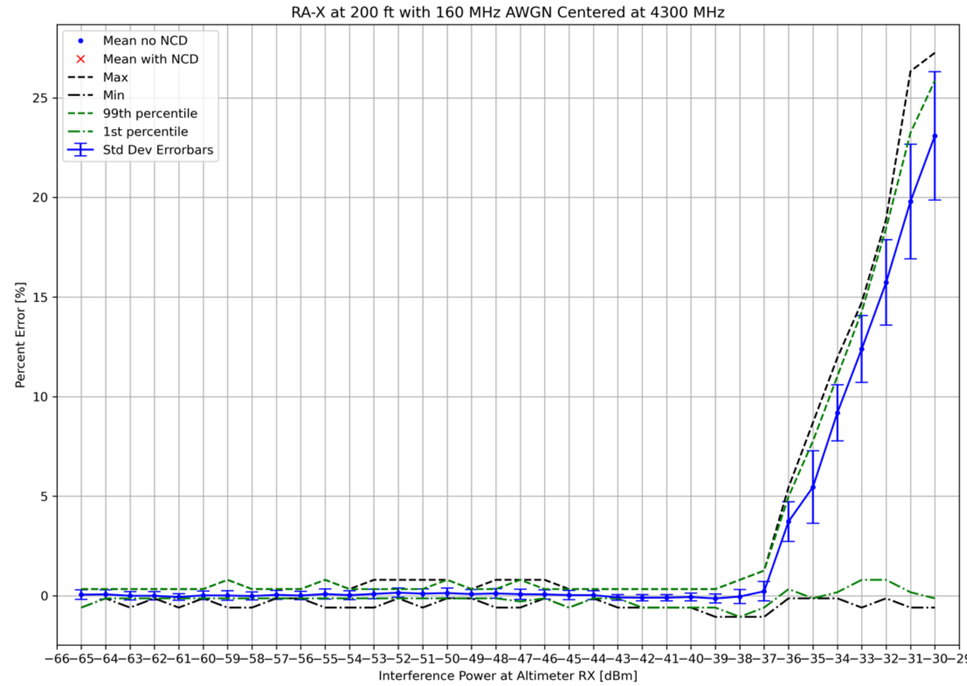

Figure 4-11: UC1 RA-X 200’ AGL Statistics with AWGN at 4300 MHz – Zoomed Out

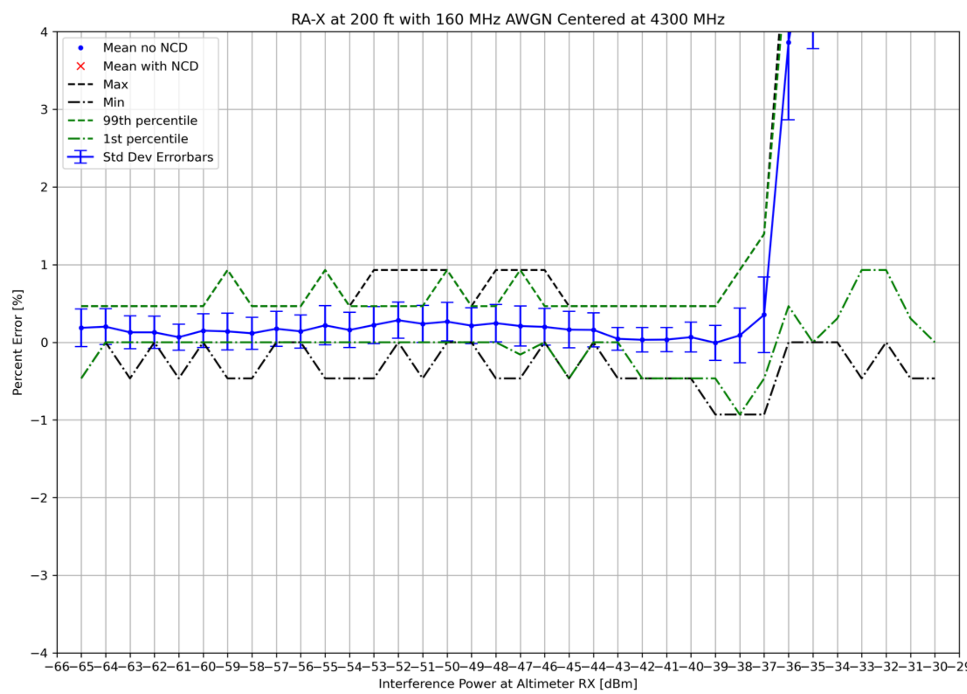

Figure 4-12: UC1 RA-X 200’ AGL Statistics with AWGN at 4300 MHz – Zoomed In

4.4.1.6 Altimeter Y

Table 4-9: UC1 RA-Y 200' AGL In-Band Spurious Emissions Break Point Summary

Center Frequency	Plot	Comments
4300 MHz	Time History Figure 4-13	Shows magnitude of change in measured height over time for increasing interference power levels.
	Statistics Figure 4-14 Figure 4-15	Mean error exceeds the ±0.5% criterion threshold at -42 dBm. 1st percentile measured height is less than the -2% criterion threshold at -42 dBm.

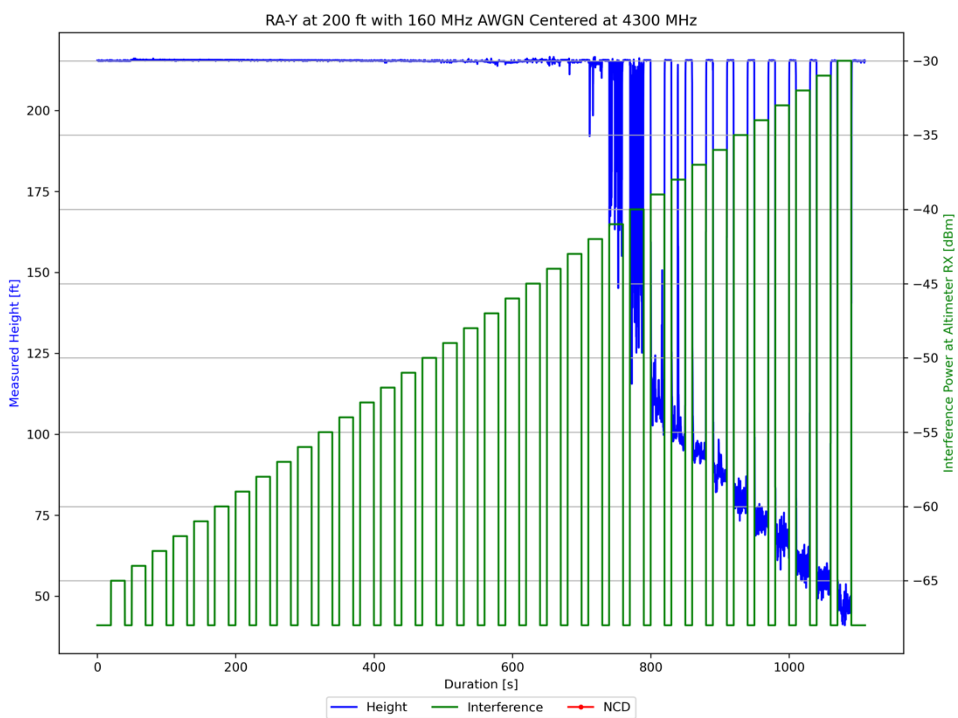

Figure 4-13: UC1 RA-Y 200' AGL Time History with AWGN at 4300 MHz

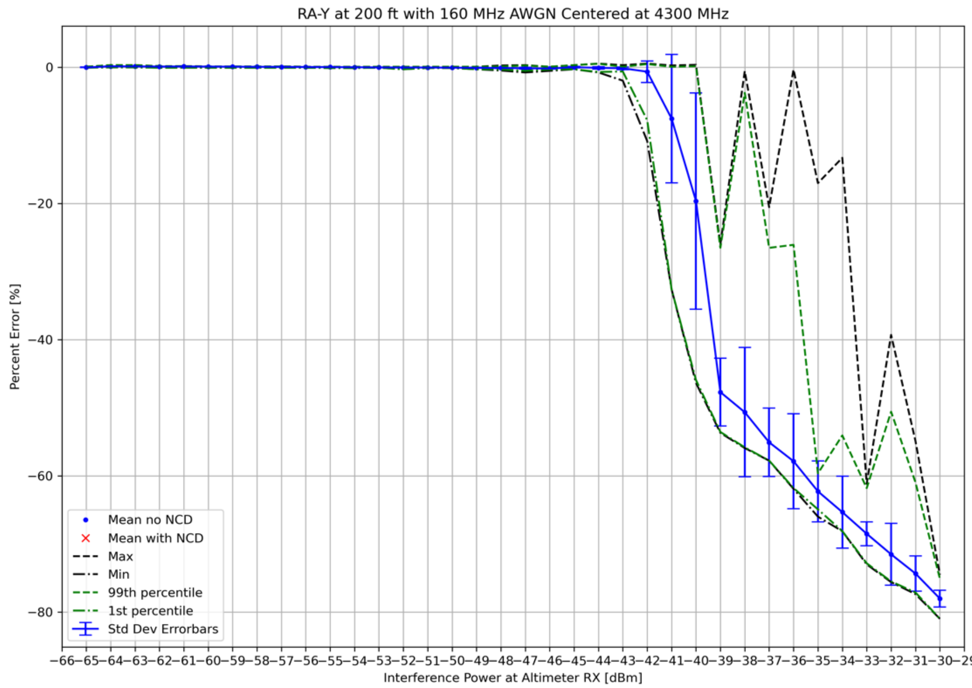

Figure 4-14: UC1 RA-Y 200' AGL Statistics with AWGN at 4300 MHz – Zoomed Out

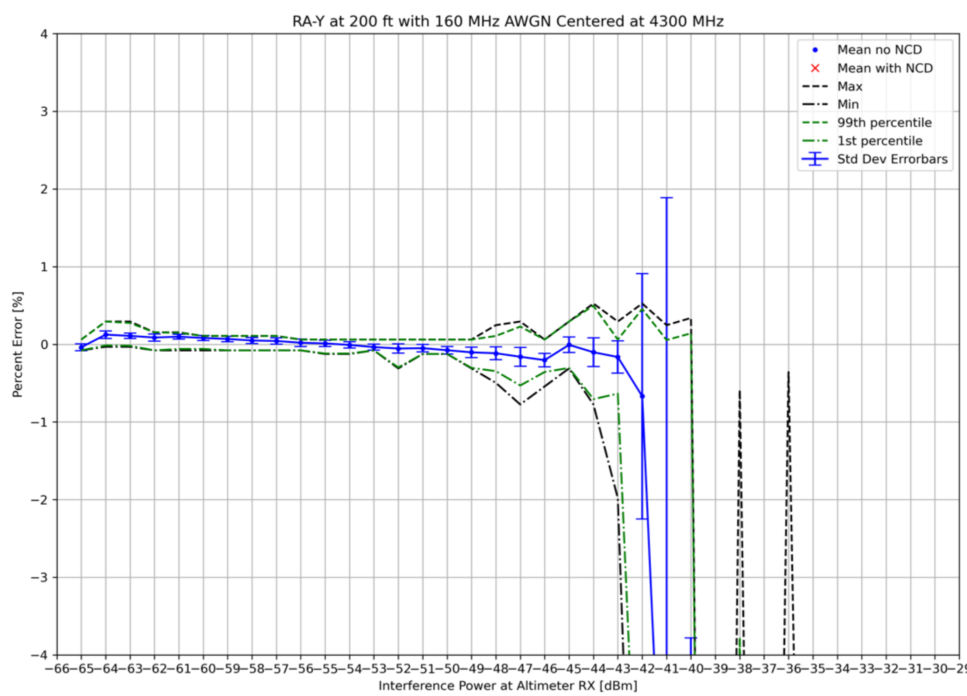

Figure 4-15: UC1 RA-Y 200' AGL Statistics with AWGN at 4300 MHz – Zoomed In

4.4.2 1000 Feet AGL

4.4.2.1 Summary

Table 4-10: UC1 1000' AGL Test Conditions

Source	Rationale	Signal Type	Characteristics	Setting
VSG	5G Spurious IBI	AWGN	160 MHz centered at 4300 MHz	Power Sweep
VCOs 1-2	Own-ship multiplex installation	FMCW	CF: 4300 MHz BW/Sweep Rate per AUT	ON
VCOs 3-16	WCLS – other aircraft	FMCW		OFF

Table 4-11: UC1 1000' AGL In-Band Spurious Emissions Break Points

Altimeter	1000 ft, Own-Ship VCOs			
	4300 MHz			
	ME	**1%**	**99%**	**NCD**
F	-57 dBm	-57 dBm	NB	NB
L	NB	NB	NB	-51 dBm
T	-47 dBm	-46 dBm	-45 dBm	-45 dBm
X	-57 dBm	-56 dBm	NB	-48 dBm
Y	-56 dBm	-56 dBm	NB	NB
ITM	-63 dBm			
PSD	-85 dBm/MHz			

4.4.2.2 Altimeter F

Table 4-12: UC1 RA-F 1000' AGL In-Band Spurious Emissions Break Point Summary

Center Frequency	Plot	Comments
4300 MHz	Time History Figure 4-16	Shows magnitude of change in measured height over time for increasing interference power levels.
	Statistics Figure 4-17 Figure 4-18	Mean error exceeds the ±0.5% criterion threshold at -57 dBm. 1st percentile measured height is less than the -2% criterion threshold at -57 dBm.

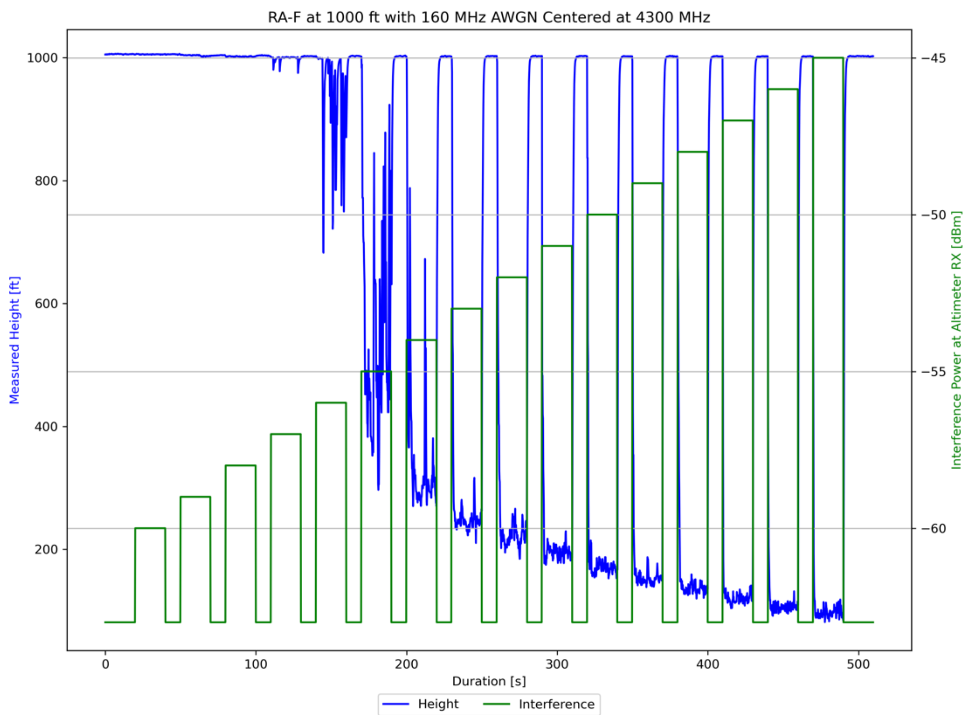

Figure 4-16: UC1 RA-F 1000' AGL Time History with AWGN at 4300 MHz

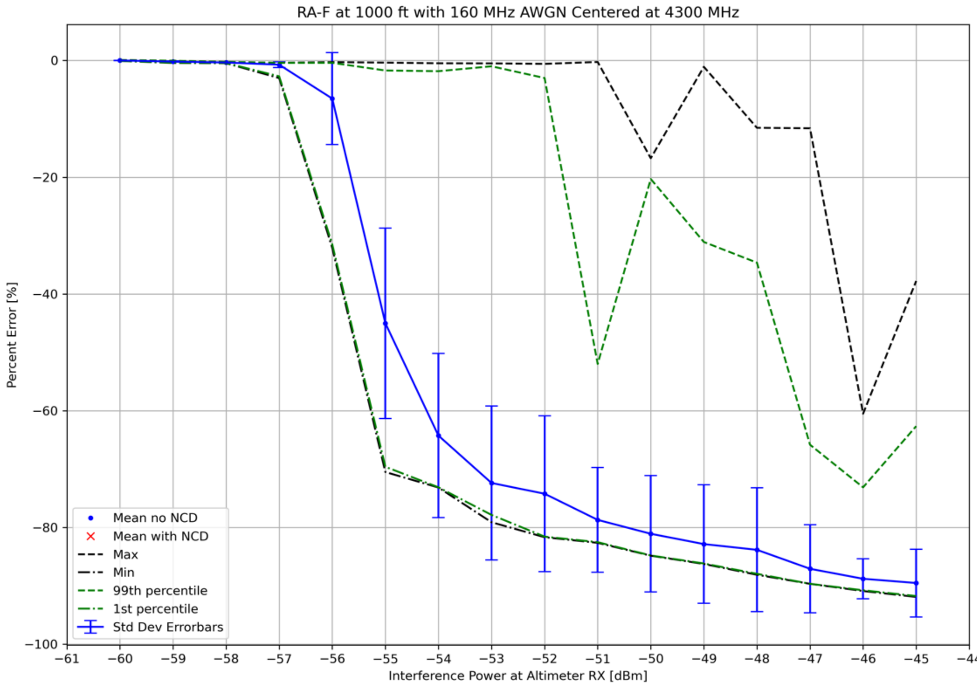

Figure 4-17: UC1 RA-F 1000' AGL Statistics with AWGN at 4300 MHz – Zoomed Out

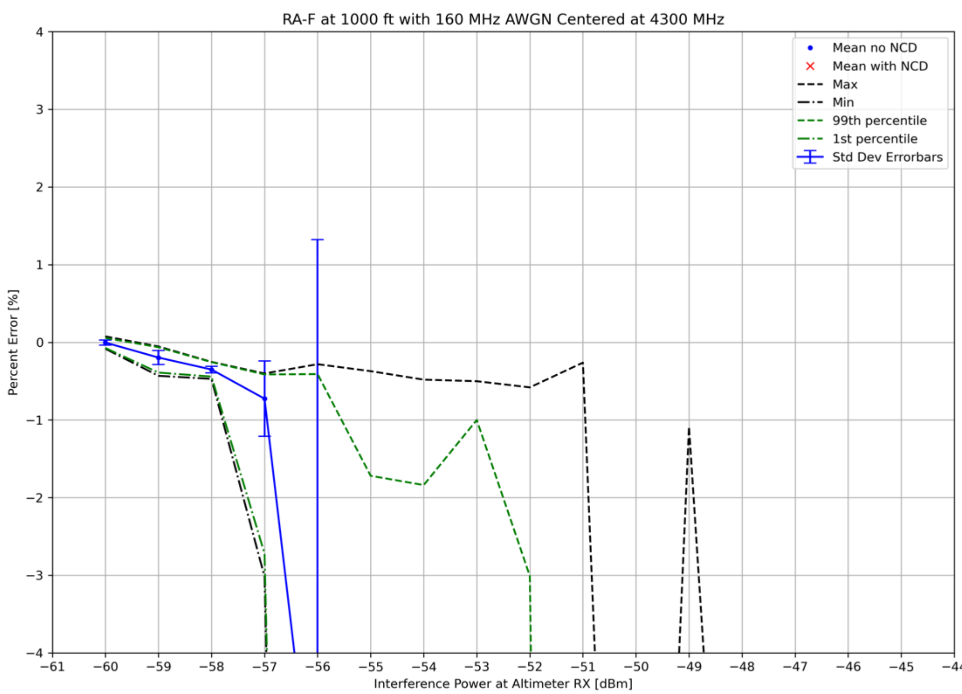

Figure 4-18: UC1 RA-F 1000' AGL Statistics with AWGN at 4300 MHz – Zoomed In

4.4.2.3 Altimeter L

Table 4-13: UC1 RA-L 1000' AGL In-Band Spurious Emissions Break Point Summary

Center Frequency	Plot	Comments
4300 MHz	Time History Figure 4-19	Shows magnitude of change in measured height over time for increasing interference power levels.
	Statistics Figure 4-20	An NCD occurs at -51 dBm.

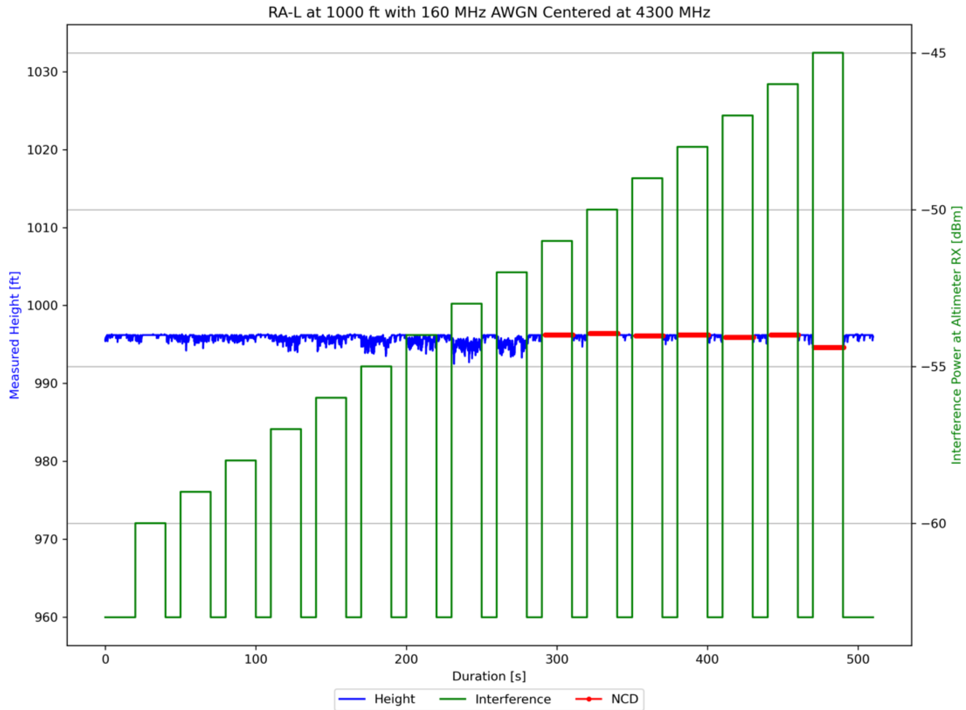

Figure 4-19: UC1 RA-L 1000' AGL Time History with AWGN at 4300 MHz

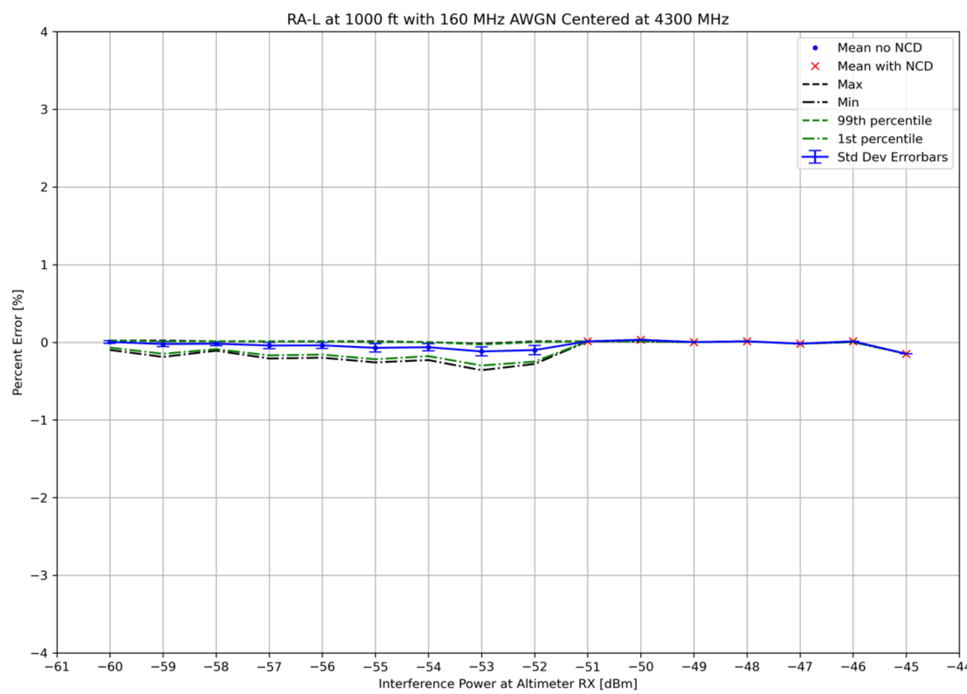

Figure 4-20: UC1 RA-L 1000' AGL Statistics with AWGN at 4300 MHz

4.4.2.4 Altimeter T

Table 4-14: UC1 RA-T 1000' AGL In-Band Spurious Emissions Break Point Summary

Center Frequency	Plot	Comments
4300 MHz	Time History Figure 4-21	Shows magnitude of change in measured height over time for increasing interference power levels.
	Statistics Figure 4-22 Figure 4-23	Mean error exceeds the ±0.5% criterion threshold at -47 dBm. 1st percentile measured height is less than the -2% criterion threshold at -46 dBm. An NCD occurs at -45 dBm. 99th percentile measured height is greater than the +2% criterion threshold at -45 dBm.

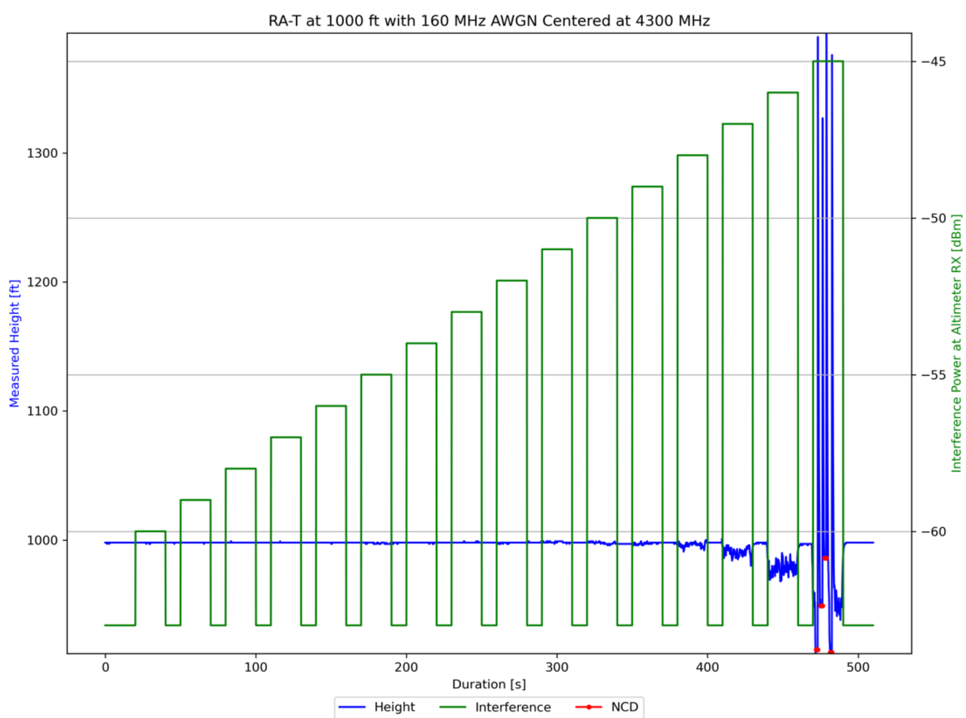

Figure 4-21: UC1 RA-T 1000' AGL Time History with AWGN at 4300 MHz

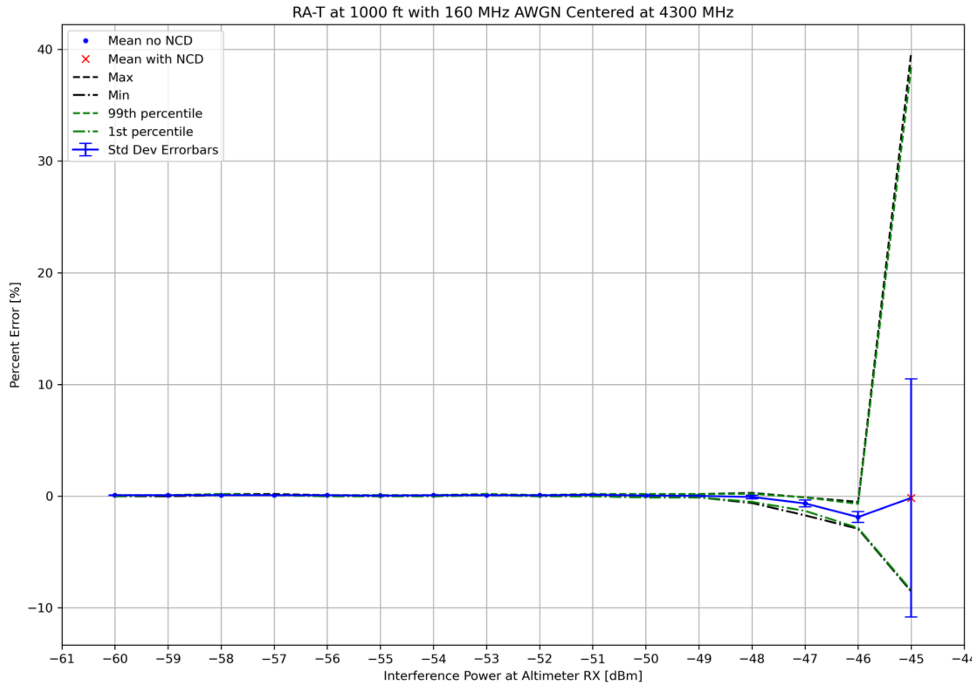

Figure 4-22: UC1 RA-T 1000' AGL Statistics with AWGN at 4300 MHz – Zoomed Out

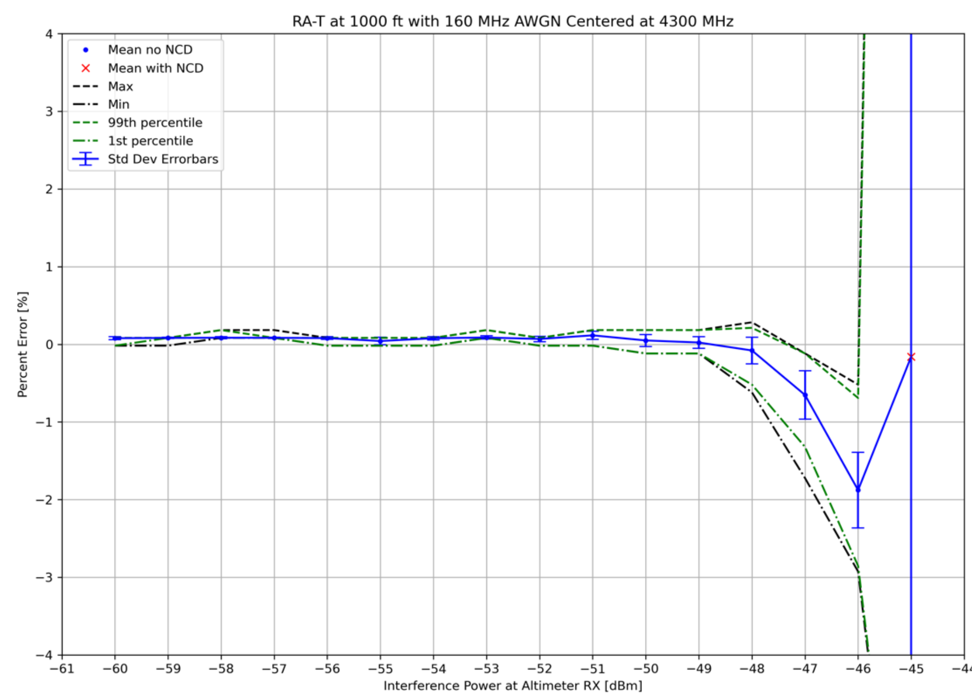

Figure 4-23: UC1 RA-T 1000' AGL Statistics with AWGN at 4300 MHz – Zoomed In

4.4.2.5 Altimeter X

Table 4-15: UC1 RA-X 1000' AGL In-Band Spurious Emissions Break Point Summary

Center Frequency	Plot	Comments
4300 MHz	Time History Figure 4-24	Shows magnitude of change in measured height over time for increasing interference power levels.
	Statistics Figure 4-25 Figure 4-26	Mean error exceeds the ±0.5% criterion threshold at -57 dBm. 1st percentile measured height is less than the -2% criterion threshold at -56 dBm. An NCD occurs at -48 dBm.

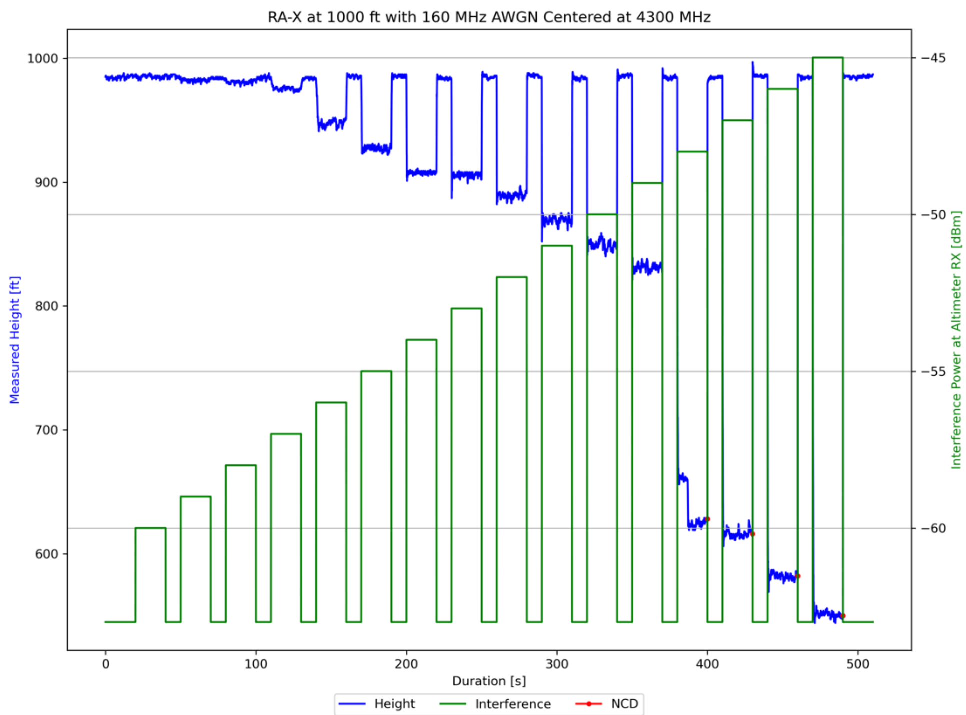

Figure 4-24: UC1 RA-X 1000' AGL Time History with AWGN at 4300 MHz

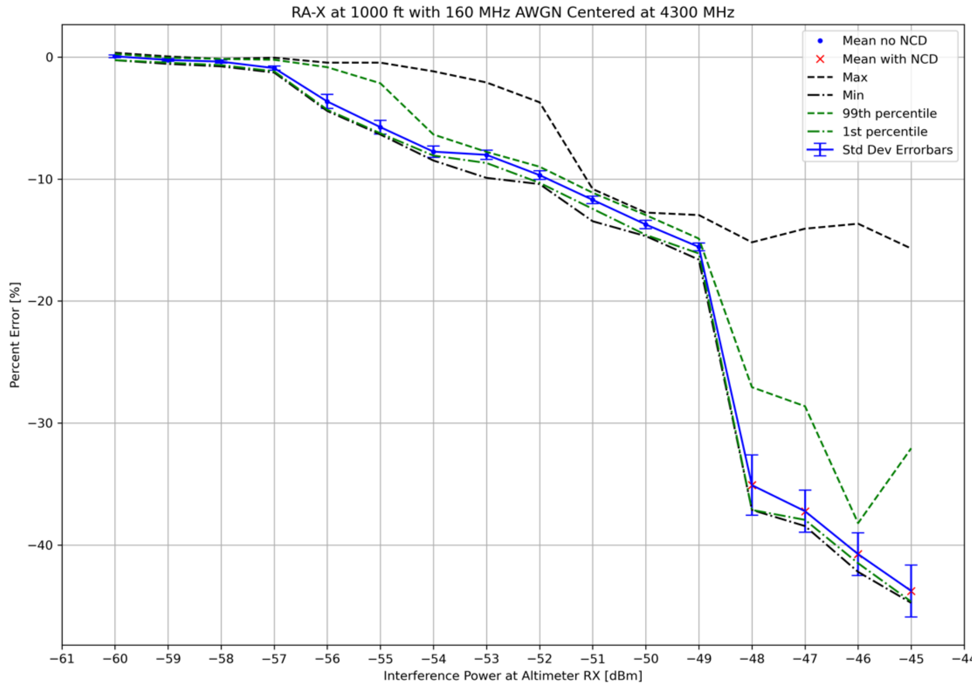

Figure 4-25: UC1 RA-X 1000' AGL Statistics with AWGN at 4300 MHz – Zoomed Out

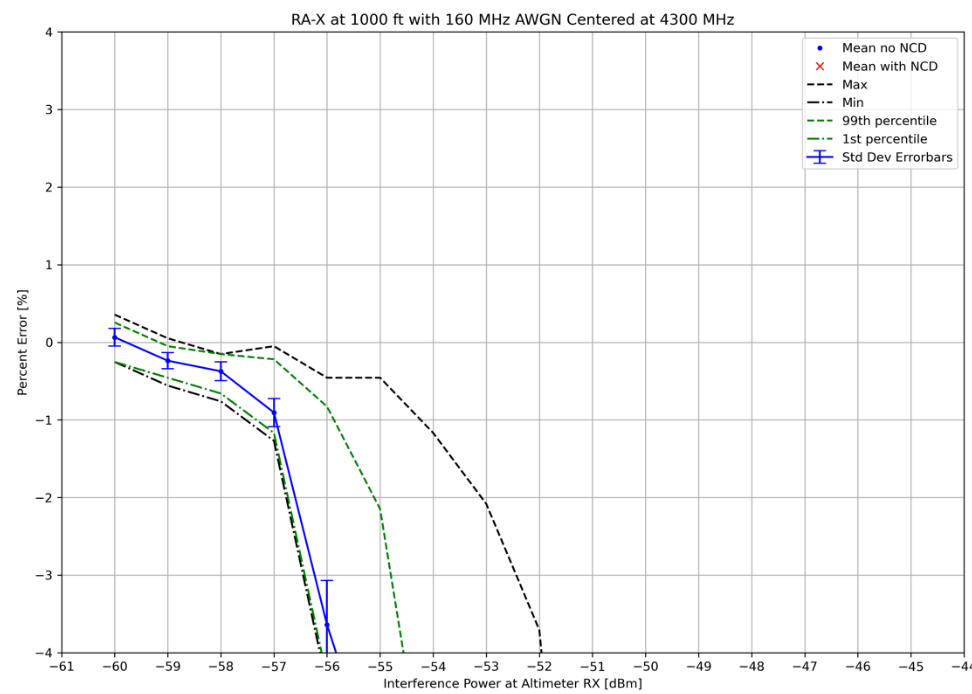

Figure 4-26: UC1 RA-X 1000' AGL Statistics with AWGN at 4300 MHz – Zoomed In

4.4.2.6 Altimeter Y

Table 4-16: UC1 RA-Y 1000’ AGL In-Band Spurious Emissions Break Point Summary

Center Frequency	Plot	Comments
4300 MHz	Time History Figure 4-27	Shows magnitude of change in measured height over time for increasing interference power levels.
	Statistics Figure 4-28 Figure 4-29	Mean error exceeds the ±0.5% criterion threshold at -56 dBm. 1st percentile measured height is less than the -2% criterion threshold at -56 dBm.

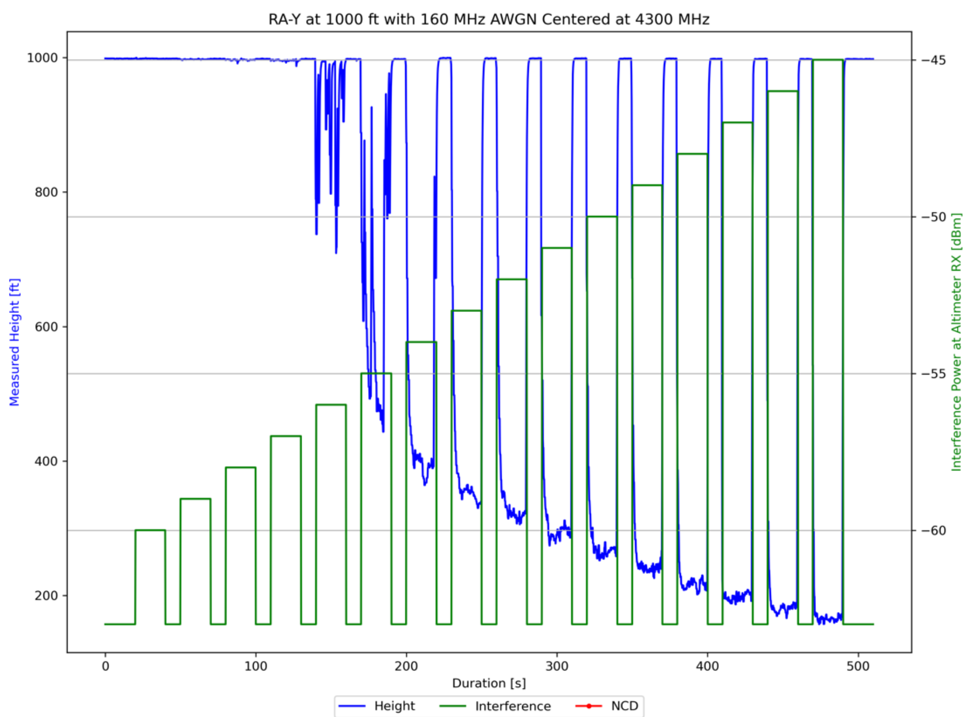

Figure 4-27: UC1 RA-Y 1000’ AGL Time History with AWGN at 4300 MHz

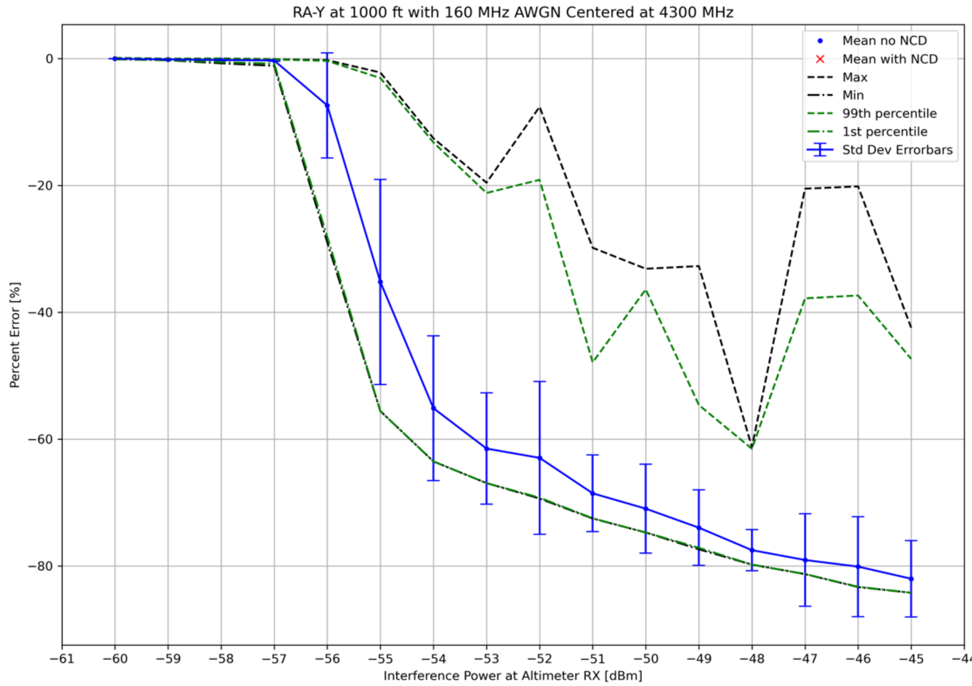

Figure 4-28: UC1 RA-Y 1000' AGL Statistics with AWGN at 4300 MHz – Zoomed Out

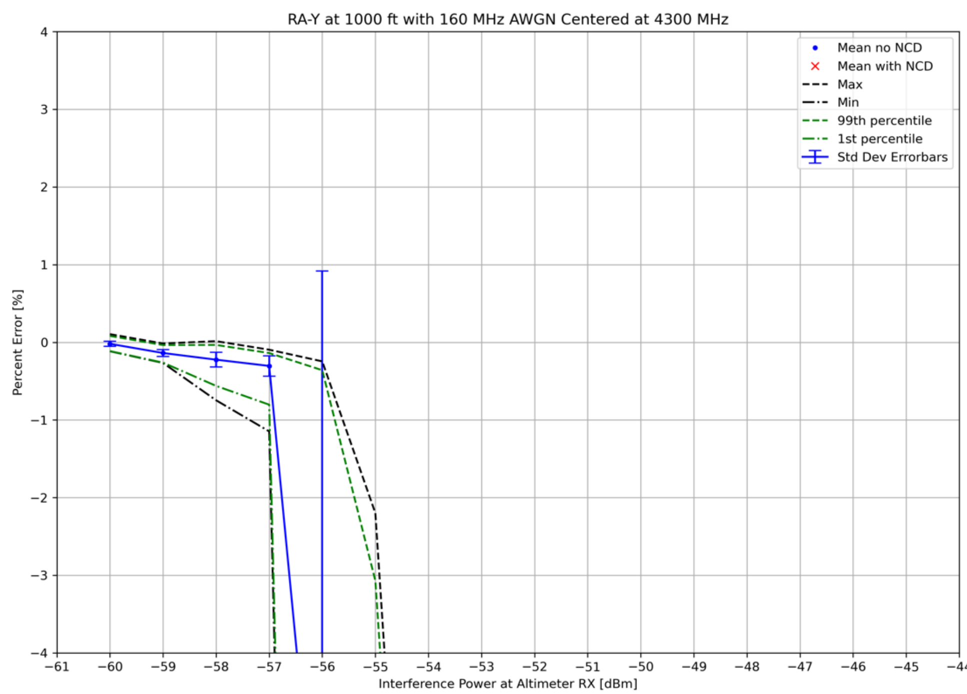

Figure 4-29: UC1 RA-Y 1000' AGL Statistics with AWGN at 4300 MHz – Zoomed In